 MI Prof. Fire Fighters Union

Study: Firefighters face higher cancer rates

By JAMES WALKER

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REGION — One of the most dangerous occupations in the world is becoming even more hazardous for its workers — but a new study suggests that the people we expect to protect us are not being adequately protected against the risks of their profession.

A study released by the University of Cincinnati has determined that firefighters are at a greater risk of developing four different types of cancer than the general population — and also suggests the protective equipment firefighters are using is insufficient in protecting them against cancer-causing agents.

In a report by the university's environmental health department, researchers found that firefighters are twice as likely to develop testicular cancer and have significantly higher rates of non-Hodgkin's lymphoma and prostate cancer than people in other professions — and overall found 10 cancers that were either possibly or probably related to firefighting.

The report also confirmed previous findings that firefighters are at greater risk for multiple myeloma, which is a cancer of the bone marrow for which there is currently no known cure.

The research is the largest comprehensive study to date investigating cancer risk associated with working as a firefighter and concludes that firefighters need better protection on the job.

The findings were published in the November issue of the Journal of Occupational and Environmental Medicine.

Dr. Andrea Ruskin, a hematologist and oncologist at the Whittingham Cancer Center at Norwalk Hospital, said while "it's nothing that has caught our eye, it's no surprise.

"They are exposed to so much," she said. Ruskin said firefighters' exposure to certain carcinogens can have a devastating effect on their health.

"They can get DNA damage," she said. However, Ruskin said not every firefighter on the job will get cancer, much the same as that not every smoker will develop lung cancer.

"It's a combination of exposure and genetic predisposition," she said.

Research shows that environment, including diet and lifestyle, causes up to 90 percent of all cancer.

The team of researchers at Cincinnati analyzed information on 110,000 firefighters from around the nation — most of them full-time, white male workers — from 32 previously published scientific studies.

Researchers believe there is a direct correlation between the chemical exposures firefighters experience on the job and their increased risk for cancer.

Fire Chief Denis McCarthy said there have been "dramatic changes" in the equipment that firefighters at the Norwalk Fire Department use for protection.

McCarthy said during the past 10 years, there have been significant upgrades in the breathing apparatus firefighters use, which went from "one-size-fits-all" to a custom fit. New regulations also have prevented recontamination by adopting standards to clean firefighters' "turn-out gear," which are the coats, pants and helmets firefighters wear; and all fire stations are equipped with diesel exhaust removal systems.

According to the study, firefighters are exposed to many compounds that the International Agency for Research on Cancer has designated carcinogens. These include benzene, diesel engine exhaust, chloroform, soot, styrene and formaldehyde.

The substances can be inhaled or absorbed through the skin and occur both at the scene of a fire and in the firehouse — where idling diesel fire trucks produce exhaust.

"Stations are not only living quarters, but it's a garage, too," McCarthy said. "We have the latest standard for protection against airborne agents."

Researchers at Cincinnati studied the risk for 20 different cancers.

The epidemiologists found that half the studied cancers — including testicular, prostate, skin, brain, rectum, stomach and colon cancer, non-Hodgkin's lymphoma, multiple myeloma and malignant melanoma — were associated at varying levels of increased risk with firefighting.

Researchers found firefighters have a 100-percent higher risk of developing testicular cancer, a 50-percent higher risk for multiple myeloma and non-Hodgkin's lymphoma, and for prostate cancer it's a 28-percent increased risk, compared with nonfirefighters.

"There's a critical and immediate need for additional protective equipment to help firefighters avoid inhalation and skin exposures to known and suspected occupational carcinogens," said Dr. James Lockey, a professor of environmental health and pulmonary medicine at Cincinnati, and the lead researcher of the study. "In addition, firefighters should meticulously wash their entire body to remove soot and other residues from fires to avoid skin exposure."

Lockey said that firefighters exposure to carcinogenic toxins "occur not when they are in the fire, but when they are in the vicinity of the fire."

According to information from the American Cancer Society, workplace exposure is often considerably higher than general environmental exposure. And while the society does not play a direct role in classifying or identifying carcinogens, it does provide information and guidance on environmental cancer risks.

The effect of environmental exposure was brought home in a recent report that found that nearly 70 percent of rescue personnel and workers who responded to the Sept. 11, 2001, terrorist attacks on the World Trade Center suffered from lung problems during and after the recovery efforts.

Mike Dubron, president and founder of the Los Angeles-based Firefighter Cancer Network, said his organization will establish regional directors throughout the nation this year.

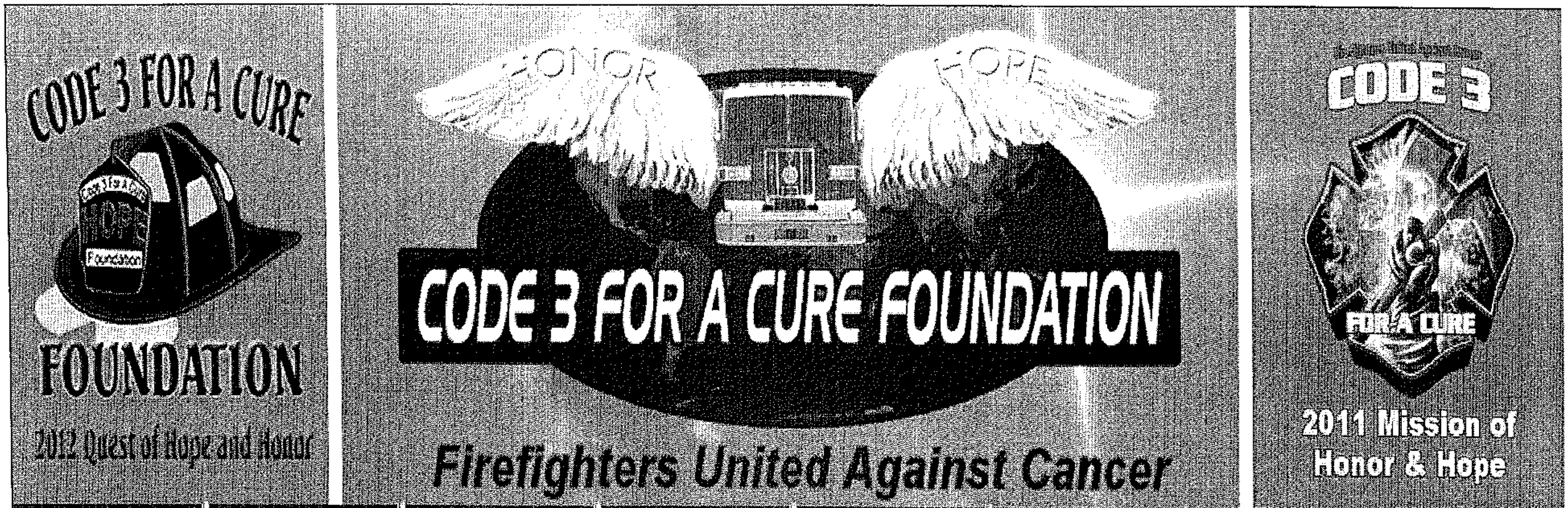
Dubron said he established the network because firefighters are largely "alpha males that don't reach out to others" about private health issues.

"All (cancers) are alarmingly increasing for firefighters," he said.

Amanda Harper, a spokeswoman with the public relations department at the University of Cincinnati, said the situation with firefighters is very real.

"These people are public servants and need to be protected," she said.

For more information on the Firefighter Cancer Network, call 1-866-994-3276; or e-mail mdubron@lacofd.org; or visit the Web site at www.firefightercancernetwork.org.



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FIREFIGHTERS AND CANCER

Numerous studies have proven that the risk of being diagnosed with cancer is higher among firefighters than the general population. One such study, conducted in 2006 by the American College of Occupational and Environmental Medicine, reviewed 32 studies on firefighters to determine the cancer risk. The study's results confirmed previous findings of an elevated risk for multiple myeloma, non-Hodgkin lymphoma, prostate, and testicular cancers. Eight additional cancers were listed as having a "possible" association with firefighting. In a three-year study completed in 2005 by the University of Cincinnati, researchers concluded that firefighters face a 102% greater chance of contracting testicular cancer than any other type of worker, a 53% greater chance of multiple myeloma, a 51% greater chance of non-Hodgkin lymphoma, a 39% greater chance of skin cancer, a 32% greater chance of brain cancer, a 28% greater chance of prostate cancer, a 22% greater chance of stomach cancer, and a 21% greater chance of colon cancer. "Firefighters are exposed to numerous cancer-causing substances," said head researcher Grace LeMasters. "I think obviously they have not got enough protection from that

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exposure. We feel that the protective gear that protects them from acute exposures, such as heat and carbon monoxide, doesn't protect them from the chemical residues that cause cancer."

Photo by Scott Fisher
Rhinebeck, NY Fire Department
2009 IAFC Photo Contest Winner

But in spite of numerous findings pointing to an increased cancer risk among firefighters, as well as presumptive laws that have been passed in certain states, it is still an uphill battle for many firefighters to try to prove that their cancer is job related so they can get the medical care they need. According to an article written by the International Association of Firefighters, Dave Potter had been a dedicated firefighter in Puyallup, Washington, for 16 years in 2005 when he learned he had T-cell lymphocytic leukemia. Potter contracted the cancer as a result of dangerous toxins he had been exposed to on the job. Even though Washington had enacted presumptive laws, Potter died before he received the treatment he needed. "He died because he needed a bone marrow transplant, and could not afford the $60,000 cost of the procedure," explained Kevin Rojecki, legislative liaison for the Washington State Council of Firefighters. "He died because his workers compensation claim was denied."

Bill Humbert, a retired Portland, Oregon firefighter, had been on the job 10 years when he found a lump on his neck that turned out to be non-Hodgkins Lymphoma. He, too, was sick due to on-the-job exposure. At the time Oregon did not have presumptive laws. Humbert's cancer is currently in remission, and he is advocating on behalf of other firefighters to pass presumptive legislation in Oregon.

Like Humbert, Code 3 for a Cure President and Founder Lorenzo Abundiz experienced the same type of nightmare in 1998 while still on active duty, after serving for 26 years as a Firefighter, when he found a lump on his right rear chest wall that turned out to be leiomyosarcoma, a rare and highly aggressive cancer that attacks the muscle tissue and can quickly spread. Abundiz's employer denied his request for workers' compensation benefits, claiming that his cancer was

Photo by Craig Allyn Rose
San Jose, CA Fire Department
2010 IAFC Photo Contest Honorable Mention

not caused by his firefighting career. Having never smoked a cigarette in his life, Abundiz found it hard to believe that the cancer was not caused by his firefighting career. Because the City initially denied his claim for benefits, Abundiz's much needed surgery was delayed by one month because of the lengthy HMO approval process. By the time he finally got the surgery he needed, the tumor had grown to the size of a golf ball and had spread. In spite of an oncologist's testimony to the contrary, Abundiz ultimately lost his workers' compensation case in court.

As the above cases illustrate, in addition to going through the trauma of a cancer diagnosis, surgery and/or treatment, firefighters not covered under workers' compensation often end up having to pay hefty bills for their medical care, their medical care is delayed, or they don't receive the critical care they need because they cannot afford it, as in Dave Potter's case. In addition to the stress of trying to prove their cancer was job related (if they have the energy or the means to do so), the financial stress caused by escalating medical bills only adds to the stress they are already under and further undermines the healing process.

The fact that cancer affects millions of people all over the world, and the fact that there is a proven correlation between firefighting and cancer, confirm both the need to eradicate the terrible disease and, until a cure is found, help alleviate the suffering of its victims; more specifically, its firefighter victims. There are currently no known organizations that provide financial relief specifically for active or retired firefighters diagnosed with cancer, and there is currently a lack of an adequate system to ensure they receive the critical health care and support they need. Although there is no known statistical data identifying exactly how many firefighters are in financial distress due to a cancer diagnosis, it can be easily surmised that there is a definite need for programs designed specifically for them, based on both their elevated risk of contracting the disease and the lack of affordable critical health care.

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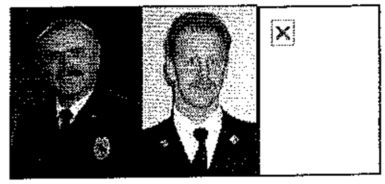
Pushing for Presumptive Protections



From left: Puyallup, WA Local 726 member Dave Potter, who died from Leukemia; Portland, OR Local 43 member Steve Higley, who died from non-Hodgkins lymphoma; and retired Portland, OR Local 43 member William Humbert, whose cancer is currently in remission. In all three cases, the cancers resulted from on-the-job exposure.

Dave Potter had been a dedicated fire fighter in Puyallup, Washington, for 16 years in 2005 when he learned he had T-cell Lymphocytic Leukemia. Potter contracted the cancer as a result of dangerous toxins he had been exposed to on the job.

Bill Humbert, a retired Portland, OR Local 43 fire fighter, had been on the job 10 years when he found a lump on his neck that turned out to be non-Hodgkins Lymphoma. He, too, was sick due to on-the-job exposure.

At the time, neither Washington nor Oregon had enacted presumptive laws. Potter died before he received the treatment he needed. Humbert's cancer is currently in remission, and he is advocating on behalf of other fire fighters to pass presumptive legislation in Oregon.

Meanwhile, fire fighters in Washington can hope there will be no more stories like Dave Potter's. The state's presumptive laws were amended in April to include additional cancers, thanks to aggressive lobbying by the Washington State Council of Fire Fighters (WSCFF) and expert testimony from the IAFF. The IAFF also helped pass similar legislation in Colorado and Vermont, and has testified in four more states: Oregon, Connecticut, Missouri and Michigan. And, Illinois added presumptive legislation for workers compensation in May. Florida and North Carolina are also working to pass presumptive legislation for its fire fighters.

"An astounding 90 percent of fire fighter deaths are due to occupationally related illnesses," says IAFF General President Harold Schaitberger. "Our members put their lives on the line every day to protect their communities, and shouldn't have to worry what will happen to them and their families if they get sick. Yet some states still do not provide presumptive protections for fire fighters who contract certain cancers and other illnesses in the course of their duties."

More than 40 states and six provinces (click here to read about Ontario) currently recognize certain illnesses as occupational hazards of fire fighting and have enacted laws presuming these illnesses are job-related, safeguarding workers compensation and retirement disability benefits for fire fighters.

The Washington State Council of Fire Fighters worked closely with the fire chiefs and other groups to pass presumptive legislation. Washington Governor Christine Gregoire signed the bill in April.

In Washington, Governor Christine Gregoire signed a bill to amend the state's current presumptive laws to include heart attacks and add prostate cancer, colorectal cancer, multiple myeloma and testicular cancer to the list of presumed cancers. "Our ongoing relationships with the Washington Fire Chiefs and other groups with great political influence was what really led to our success," says Kelly Fox, president of WSCFF. "That and expert testimony from the IAFF."

This legislation could have saved Dave Potter's life. "He died because he needed a bone marrow transplant, and could not afford the $60,000 cost of the procedure," explains Keven Rojecki, legislative liaison for WSCFF. "He died because his workers compensation claim was denied."

Testifying in Washington, Dr. Erika Olson, a resident physician at Johns Hopkins University and for the IAFF, said, "Fire fighters face the possibility of death or injury every time they respond to an alarm. While risk may be part of the profession, fire fighter deaths and injuries should not be accepted as part of the job."

However, neighboring Oregon State Fire Fighters Council (OSFFC) is facing opposition to its efforts to pass presumptive legislation from an unexpected adversary: the state's fire chiefs. Kelly Bach, president of the OSFFC, notes, "It is unfortunate that the Chiefs cannot support their fire fighters."

In 2006, researchers at the University of Cincinnati evaluated data from 32 previously published studies, and found that fire fighters are twice as likely as the general population to develop testicular cancer, 50 percent more likely to develop multiple myeloma or non-Hodgkin's lymphoma, and 28 percent more likely to develop prostate cancer.

In Oregon, the fire chiefs want to amend the proposed legislation to omit all but three of the cancers identified in the University of Cincinnati study.
In the last 10 years, more than 100 fire fighters have been diagnosed with cancer in Oregon. With 2,800 IAFF members in the entire state, that number is significant. Proposed legislation, currently in the state senate, would presume the following cancers to be job related for fire fighters: brain cancer, colon cancer, stomach cancer, testicular cancer, prostate cancer, and multiple myeloma or non-Hodgkins Lymphoma.

Carolyn Higley's husband, Steve, was a member of Local 43 when he died from non-Hodgkins Lymphoma in December 2004. Diagnosed in October 2003, it wasn't until September 2004 that the workers compensation board determined that Higley's cancer was caused by on-the-job exposure.

"I am thankful for the benefits," says Carolyn Higley, "but I'd rather have my husband back." Had presumptive legislation been in place, it would have alleviated much of the stress of worrying about sick leave, bills and benefits. "Those are the last things you want to think about when you go through something like this," she says.

In Vermont, a new law signed by Governor Jim Douglas on May 22, 2007, covers leukemia, lymphoma or multiple myeloma, and cancers originating in the bladder, brain, colon, gastrointestinal tract, kidney, liver, pancreas, skin or testicles. Fire fighters diagnosed with one of the presumed cancers are eligible for benefits for up to 10 years after retirement.

Vermont Governor Jim Douglas signed the state's presumptive bill at a Montpelier fire station where he was joined by PFFV President Matt Vinci.

"Over the last 10 years, we have seen a definite increase in the number of Vermont fire fighters getting cancer," says Matt Vinci, president of PFFV. Vermont won presumptive heart legislation three years ago, and PFFV has since been working to get the same protections for cancer. Vinci credits PFFV political action and support from the IAFF and IAFF 3rd District Vice President Mike Mullane for securing the votes in the state House and Senate. Championing the bill in the state legislature were the bill's chief sponsor, Senator Vince Illuzzi (R), and Representative Helen Head (D).

With his signature on the legislation pending, IAFF President Schaitberger, DVP Mullane and PFFV President Vinci met with Governor Douglas during the Professional Fire Fighters of Vermont state convention earlier in May. "The governor had reservations about signing the bill," says Schaitberger. "But we made it clear to Governor Douglas that he needed to do the right thing and protect fire fighters in his state." Following the meeting, Douglas promised to sign the legislation. "He made good on that promise," Schaitberger says.

Meanwhile, in Colorado, thanks to aggressive lobbying efforts by IAFF 9th District Vice President Randy Atkinson, the Colorado Professional Fire Fighters (CPFF) and the IAFF, Colorado Governor Bill Ritter signed presumptive legislation on May 17, 2007. The bill was sponsored by Senator Joan Fitz-Gerald (D) and Representative Mike Cerbo (D).

The Workers Compensation Act of Colorado now provides benefits to fire fighters who contract cancer of the brain, skin, digestive system, hematological system or genitourinary system as the result of on-the-job exposures. Claims can only be denied if proven the fire fighter had a pre-existing condition. "This was a tough battle," says Atkinson. "We could not have done it without the IAFF's assistance and expert testimony." Dr. Virginia Weaver, an associate professor at Johns Hopkins University Bloomberg School of Public Health, testified on behalf of CPFF.

In other states, the fight for presumptive protections continues. The Uniformed Professional Fire Fighters Association of Connecticut hopes to pass legislation that would ensure that occupational illnesses are presumed job related for the purposes of workers compensation and disability retirement. However, the Connecticut Conference of Municipalities is opposing the bill, maintaining it will cause a financial strain on the state's workers compensation and municipality budget.

The Connecticut bill has made its way through several house committees and is on its way to the house floor for consideration. If current language stays intact, some protections would be in place for all strains of hepatitis, meningitis, tuberculosis, heart disease, myeloma, non-Hodgkin's Lymphoma, prostate cancer and testicular cancer.

As scientific evidence continues to demonstrate the increased risk for heart disease, lung disease, cancer and infectious diseases among fire fighters and emergency medical responders, the IAFF encourages its affiliates to work with state and provincial legislatures to enact presumptive laws and to update and enhance existing legislation where laws vary or provide limited benefits.

The IAFF has developed a database of current presumptive disability provisions in the United States and Canada. Click here to review the presumptive disability provision in your state or province.

In addition, the IAFF has made fire fighter presumptive legislation a focus of its lobbying efforts and is developing an international database of fire fighters with heart disease, lung disease, infectious disease and cancer in order to actively track statistics for these illnesses in fire fighters. This statistical information — minus any identifying data — is available to IAFF members for use in lobbying for presumptive disability laws.

For more information, contact the IAFF Division of Occupational Health and Safety at (202) 824-1571.

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Cancer Risk Among Firefighters: A Review and Meta-analysis of 32 Studies

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Objective: *The objective of this study was to review 32 studies on firefighters and to quantitatively and qualitatively determine the cancer risk using a meta-analysis.* ***Methods:*** *A comprehensive search of computerized databases and bibliographies from identified articles was performed. Three criteria used to assess the probable, possible, or unlikely risk for 21 cancers included pattern of meta-relative risks, study type, and heterogeneity testing.* ***Results:*** *The findings indicated that firefighters had a probable cancer risk for multiple myeloma with a summary risk estimate (SRE) of 1.53 and 95% confidence interval (CI) of 1.21–1.94, non-Hodgkin lymphoma (SRE = 1.51, 95% CI = 1.31–1.73), and prostate (SRE = 1.28; 95% CI = 1.15–1.43). Testicular cancer was upgraded to probable because it had the highest summary risk estimate (SRE = 2.02; 95% CI = 1.30–3.13). Eight additional cancers were listed as having a "possible" association with firefighting.* ***Conclusions:*** *Our results confirm previous findings of an elevated metarelative risk for multiple myeloma among firefighters. In addition, a probable association with non-Hodgkin lymphoma, prostate, and testicular cancer was demonstrated.* (J Occup Environ Med. *2006;48:1189–1202*)

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During the course of their work, firefighters are exposed to harmful substances at the fire scene as well as at the firehouse. At the fire scene, firefighters are potentially exposed to various mixtures of particulates, gases, mists, fumes of an organic and/or inorganic nature, and the resultant pyrolysis products.[1,2] Specific potential exposures include metals such as lead, antimony, cadmium, uranium, chemical substances, including acrolein, benzene, methylene chloride, polyaromatic hydrocarbons, perchlorethylene, toluene, trichloroethylene, trichlorophenol, xylene, formaldehydes, minerals such as asbestos, crystalline, and noncrystalline silica, silicates, and various gases that may have acute, toxic effects.[1,2] In some situations, respiratory protection equipment may be inadequate or not felt to be needed resulting in unrecognized exposure.[3] At the firehouse where firefighters spend long hours, exposures may occur to complex mixtures that comprise diesel exhaust, particularly if trucks are run in closed houses without adequate outside venting. In light of the World Trade Center disaster, concerns have reemerged and heightened related to building debris particle exposures from pulverized cement and glass, fiberglass, asbestos, silica, heavy metals, soot, and/or organic products of combustion.[5]

To date, only one meta-analysis conducted by Howe and Burch in 1990 examined the extent of cancer risk among firefighters in 11 mortality studies.[4] They reported that there was an increased association with the occurrence of brain tumors, malignant melanoma, and multiple myeloma with the evidence in favor of causality somewhat greater for brain tumors and multiple myeloma. Since then, there have been numerous mortality and incidence studies. Hence, the purpose of this study was twofold. The first purpose was to update the Howe and Burch findings by reviewing the methodologic characteristics of these studies and determining the probability of cancer by assessing the weight of evidence, including the calculated metarisk estimates. The second purpose was to describe a methodology for use in a meta-analysis when diverse investigations are being evaluated and summarized.

Materials and Methods

Search Strategy and Inclusion Criteria

Standardized mortality ratio (SMR), proportional mortality ratio (PMR), relative risk (RR), standardized incidence ratio (SIR), and case–control/mortality odds ratio (OR) studies related to firefighters and cancer risk were evaluated. For publication selection, at least 1 year in service as firefighters was required except for those studies basing employment on death certificates. Publications were retrieved by a search of computerized databases, including Medline (1966–December 2003), Health and Safety Science Abstracts (since 1980–December 2003), Cancerlit (1963–December 2003), NIOSHTIC and NIOSHTIC2 (up to December 2003), BIOSIS Previews (1980–December 2003), and PubMed (up to December 2003) using the following key words: firefighters, fire fighters, cancer. In addition to the computerized search, bibliographies in identified papers were reviewed for additional studies.

The search was restricted to reports published in English; abstracts and reviews were not included. Studies were excluded without basic data (eg, confidence intervals) that are necessary in the derivation of the meta-analysis risk estimate. If there was more than one article with the same or overlapping population, preference was given to the article providing more comprehensive information. The data were extracted from each article by one reviewer and was verified by another. Discrepancies identified by the second reviewer were resolved in a consensus meeting.

Likelihood of Cancer Risk. Statistically significant increases in cancer risks among firefighters were evaluated as the likelihood for cancer risk given a three-criteria assessment. The three criteria included "pattern of meta-relative risk association," "study type," and "consistency" among studies. These criteria were particularly important given the different methodologies used for evaluating cancer risk (ie, SMR, PMR, RR, SIR, and OR). These criteria were used in a forward approach as illustrated in Figure 1 in which at each stage, a new criterion was applied, and the probability of cancer risk was reassessed. The likelihood for cancer risk was given an assignment of "probable," "possible," or "not likely" patterned after the International Agency for Research on Cancer (IARC) risk assessment of human carcinogenicity in terms of weight of the evidence.[5] F1

The "pattern of metarelative risk associations" was the first criterion and included a two-step evaluation. For the

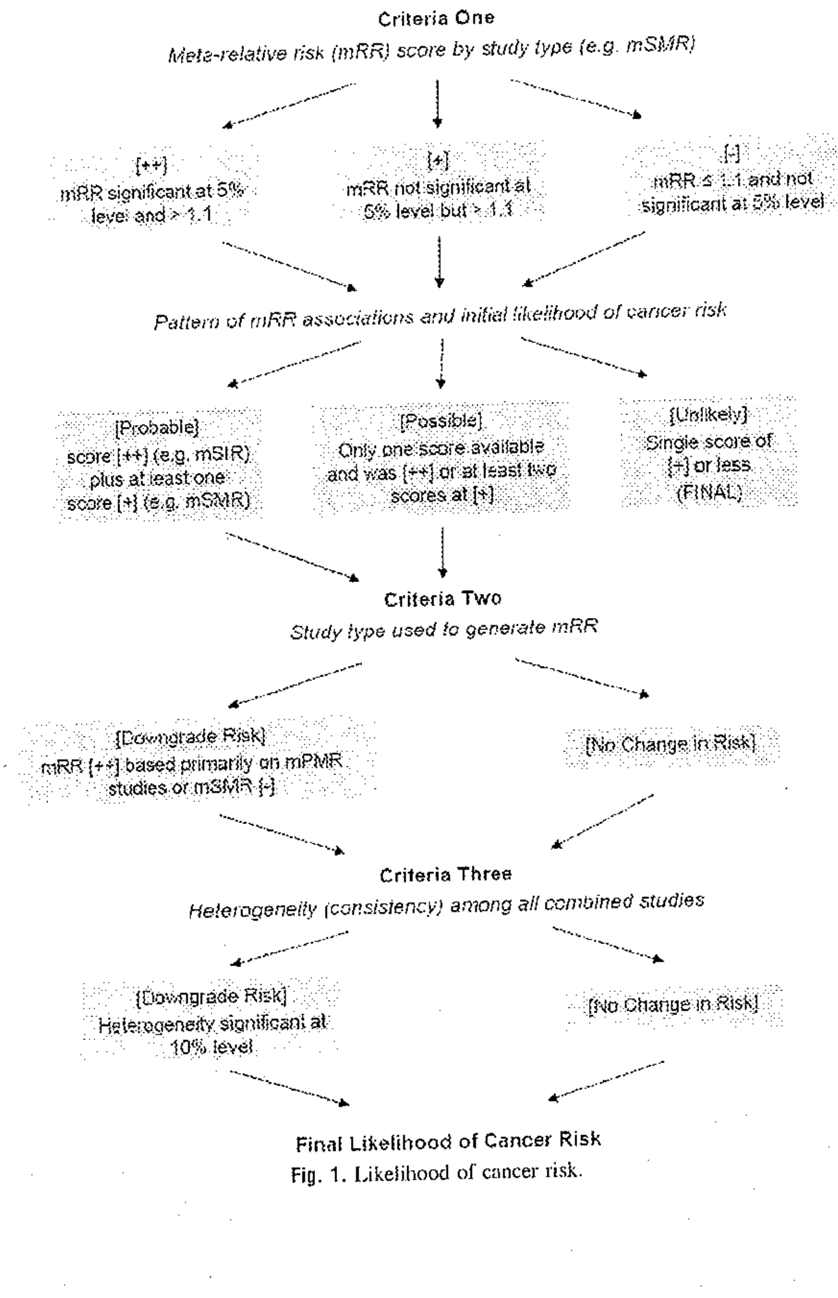

Fig. 1. Likelihood of cancer risk.

first step, the strength of the meta-analysis by each study type (eg, SMR, PMR) was assigned a score. The score of "++" was assigned if the metarelative risk was statistically significant and greater than 1.1. The score of "+" was assigned if the metarelative risk was not statistically significant, but the point risk estimate was greater than 1.1. The score of "−" was assigned if the metarelative risk was not statistically significant, and the point risk estimate was equal to or less than 1.1. At the second step, these scores were used to assign a probable, possible, or unlikely designation for the pattern of metarelative risk association. A "probable" was assigned to the cancer-specific site if one metarelative risk (ie, mSMR, mPMR, mSMR and PMR, mRR, mSIR, mOR) was statistically significant (score of ++) and at least another was greater than 1.1 (score of +). A "possible" assignment was given if only one metarelative risk was available and was statistically significant (score of ++) or if at least two metarelative risks were greater than 1.1 but were not statistically significant (score of +). "Not likely" was assigned if the cancer-specific site did not meet the probable or possible criteria.

The second criterion examined the "study type" used to generate metarelative risks. If the metarelative risk estimate reached statistical significance (score of ++), based primarily on PMR studies, the level was downgraded. PMR studies do not measure the risk of death or death rates but rather the relative frequency of that particular cause among all causes of death. Hence, the limitation of a PMR study is that the estimate may be abnormally low or high based on the overall increase or decrease in mortality and not due to the cause of interest.[6] Also, if the mSMR point risk estimate was not significant and ≤1.1 (−), the level was downgraded. The third criterion used for generating the likelihood of cancer risk was an assessment of "inconsistency" among studies. Heterogeneity testing as described in statistical methods was used to evaluate inconsistency. The level was downgraded if heterogeneity (inconsistency) testing among all combined studies had an $\alpha \leq 0.10$.

Statistical Methods

For all cancer outcomes having two or more studies, the observed and expected values from each study were summed and a metarelative risk estimate (mRR) was calculated. An mRR was calculated for each cancer by each study type, eg, SMR studies and as a summary metarelative risk across all study types. The mRR was defined as the ratio of the total number of observed deaths or incident cases to the total number of expected deaths or incident cases as follows:

$$mRR = \frac{\sum_{i=1}^{n} O_i}{\sum_{i=1}^{n} E_i}$$

where O_i denotes observed deaths (cases) in each individual study, E_i denotes expected deaths (cases), and n is the total number of studies.[7] The 95% confidence interval (CI) of mRR may be computed using the Poisson probability distribution as described by Breslow and Day.[8] The standard error (SE) for the metarelative risk is calculated as $SE = \frac{1}{\sqrt{\sum W_i}}$ where W_i is the statistical weight for a given study defined as $1/SE_i^2$ and SE_i is the standard error for a given study.

In the absence of heterogeneity, the fixed-effect model was applied for deriving the metarelative risk estimate; otherwise, the random-effects model was used. A test for heterogeneity for the fixed-effect approach is given by $Q = \sum_{i=1}^{n} W_i * \{\log(RR_i) - \log(mRR)\}^2$ where RR_i and mRR are the relative risk and the metarelative risk, respectively. The hypothesis of homogeneity among studies would be rejected if Q exceeds $\chi^2_{n-1,\alpha}$. Then the random-effects model was used with a different study weight (W_i^*) that further accounts for the interstudy variation in effect size.[8] The weighing factor W_i^* in the DerSimonian and Laird random-effects model is

$$W_i^* = \frac{1}{\left[D + \left(\frac{1}{w_i}\right)\right]}$$

where W_i is the statistical weight for a given study for the fixed-effect model and is equal to $1/SE_i^2$ with SE_i being the standard error for a given study according to Chen and Seaton[9]

$$D = \frac{[Q - (n - 1)] * \sum_{i=1}^{n} W_i}{\left(\sum_{i=1}^{n} W_i\right)^2 - \sum_{i=1}^{n} W_i^2}$$

It should be noted that D is set to 0 if $Q < n - 1$. The random-effects model was validated against data provided in Petitti,[10] which after application using our equations gave identical results. For this study, an $\alpha \leq 10\%$ or less for declaring heterogeneity was adopted.[11]

The SAS software was used to perform the calculations and validated our program for the fixed-effect model using data from different studies compiled by Howe and Burch[4] on standardized mortality ratios and proportional mortality ratios among firefighters. Where there were no observed deaths or incident cases, the lower confidence interval for an individual study was set at 0.1 as suggested in the method used by Collins and Acquavella.[12] This method was compared with the data excluding studies with a zero relative risk, and the results were similar.

Results

Identification and Characteristics of Studies

The computerized literature search identified 21 U.S. and 14 non-U.S. articles.[13–47] It was determined that three studies were not eligible for the meta-analysis because of either insufficient data,[41] data were combined for firefighters and other personnel,[42] or the text was not published in English.[43] In addition, four studies[44–47] were excluded because of overlapping populations with other reports.[18,30] For example, in 1992, Demers et al[18] reported more observed and expected cancers than in the 1994 article.[46] Four additional studies[48–51] were identified in the review by Howe and Burch[4] and used in the meta-analysis. These latter four studies are not presented in Table 1. Hence, a total of 28 studies received a detailed review as shown in Table 1, which describes the study design characteristics, exposure, and outcome definitions. Sixteen were U.S. studies and 12 were non-U.S. investigations. Five studies had an internal comparison group with the remaining using regional or national comparison groups. Fourteen ascertained exposures from employment records and defined exposure as a dichotomous (yes/no) variable. The majority of the studies relied on death certificates for assessing a cancer diagnosis. Of a total of 32 articles, 26 are included in the meta-analysis as shown in Table 2. The six additional articles are case–control/mortality odds ratio studies and presented in Table 3 with one meta-analysis for non-Hodgkin's lymphoma.

T1

T2

T3

Overview of Meta-analysis

Table 2 summarizes the meta-analysis results by study type. Studies were mostly mortality and were analyzed using SMRs and PMRs. All-cause mortality had an SMR 10% less than general population rates. Mortality from all cancers was similar to the general population using SMR and RR indices, but PMR studies showed a 10% significantly higher rate (Table 2). For individual cancers, there were statistically significant elevated meta-SMR estimates for colon cancer (1.34) and multiple myeloma (1.69). PMR studies demonstrated three significantly elevated meta-PMR values that included skin (1.69), malignant melanoma (2.25), and multiple myeloma (1.42). There was one significantly elevated metarelative risk for esophageal cancer (2.03). Incidence studies showed significant meta-SIR for cancers of the stomach (1.58), prostate (1.29), and testis (1.83).

As shown in Table 3, only one cancer type, non-Hodgkin lymphoma, had two mortality OR analyses, and both were significant. The estimated mOR was essentially based on Ma et al[14] due to the much larger sample size of firefighters (n = 4800) compared with 23 for Figgs et al.[15] Odds ratios were significantly higher for buccal cavity/pharynx (5.90) and Hodgkin's disease (2.4)[14] as well as the single incidence study related to bladder cancer (2.11) and non-Hodgkin's lymphoma (3.27).[22]

The next step was to determine the likelihood of cancer risk based on the three criteria assessment. Cancers receiving "probable" and "possible" designations are shown in Table 4. Based on evaluating the first criterion "pattern of metarelative risk" for the 20 cancer sites, eight were designated as "probable," four as "possible," and eight as an unlikely risk. Based on the second criteria "study type" stomach, rectum, skin cancer, and malignant melanoma risk were downgraded because of reliance on PMR studies for statistical significance or the mSMR point risk estimate was not significant and ≤1.1.

For the third criterion, "inconsistency" among all studies caused a downgrading for only colon cancer to "possible." This inconsistency may have been related to several factors, including study type and a cohort effect. There were 14 SMR and PMR colon cancer studies with elevated meta-risk estimates of 1.34 and 1.25, respectively (Table 2). Of these 14 studies, there were 11 (78.6%) with firefighters employed on or before 1950. In contrast, there were six mRR and SIR studies with meta-risk estimates of 0.91 and 0.90, respectively, with half employed on or before 1950. It is possible that the older cohorts had higher exposures due to a lack of awareness of the hazards or use of protective equipment.

A final check on the three criteria assessment presented in Table 4 was made by calculating an overall summary of cancer risk across all studies (ie, SMR, PMR, RR, SIR, OR). There was agreement that cancer was unlikely between the criteria assessment and the not significant summary risk estimates for esophagus, liver, pancreas, larynx, lung, bladder, kidney, and Hodgkin's disease and all cancers (Table 5). Differences between the two approaches were found for cancers of the buccal cavity/pharynx and leukemia because these were designated as possible by the criteria assessment but as not significant in the summary risk estimate. The remaining cancers were all rated as probable or possible and all had significant summary risk estimates. Of note, testicular cancer received the highest summary risk estimate (OR = 2.02; 95% CI = 1.30–3.13) related to the SIR studies compared with the "possible" designation by the three criteria assessment.

T5

T4

Discussion

The meta-analysis and criteria assessment designate the likelihood of cancer among firefighters as probable for multiple myeloma and prostate cancer. Thus, the findings related to multiple myeloma are in agreement with Howe and Burch.[4] The Philadelphia firefighter study[13] was the largest cohort study reported to date investigating exposure–response relationships. For Philadelphia firefighters, the SMR results for multiple myeloma demonstrated an increasing trend with duration of employment as a firefighter: 0.73 (95% CI = 0.10–5.17) for under 9 years, 1.50 (95% CI = 0.48–4.66) for 10 to 19 years, and 2.31 (95% CI = 1.04–5.16) with six observed deaths for greater than 20 years. Except for race, there are essentially no known risk factors for multiple myeloma other than occupational exposures (eg, paints, herbicides, insecticides,

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TABLE 1
Characteristics of Studies From Electronic Search

Reference	Company Location	Design/Analysis	Study Period	Number of Workers	Comparison Group	Exposure Variable	Exposure Source	Cancer Source	Cofactors
Baris, 2001[13]	Philadelphia	Cohort mortality (SMR)	1925–1986	7789	INT/NGP/NED	1, 3, 5	ER	DC	Age
Ma, 1998[14]	24 US states	Case–control (MOR)	1984–1993	6607	INT	4	DC	DC	Age/race
Figgs, 1995[15]	24 US states	Case–control (MOR)	1984–1989	23890 (cases) 119,450 (controls)	RGP	4	DC	DC	Age
Burnett, 1994[16]	27 US states	PMR	1984–1990	5744	INT	4	DC	DC	Age
Demers, 1993[17]	4 US states	Case–control (OR)	1977–1981	692 (cases) 1683 (controls)	LGP	4	TRV	TRV	Age
Demers, 1992a[18]	Seattle, Tacoma (WA)	Cohort mortality (SMR) Incidence (SIR)	1944–1979	4528	LGP INT/LW/NGP	4	ER	DCN, TRV	Age
Demers, 1992b[19]	Seattle, Tacoma, WA Portland	Cohort mortality (SMR)	1944–1979	4546	INT/LW/NGP	2, 3	ER	DCN	Age
Beaumont, 1991[20]	San Francisco	Cohort mortality (RR)	1940–1970	3066	NGP	3, 6	ER	DCN	Age/yr
Grimes, 1991[21]	Honolulu	PMR, RR	1969–1988	205	RGP	3, 4	ER	DC	Race
Sama, 1990[22]	Massachusetts	Case–control (MOR)	1982–1986	315	LW/RGP	4, 7	TRV	TR	Age/smoke
Vena, 1987[23]	Buffalo	Cohort mortality (SMR)	1950–1979	1867	NGP	3	ER	DCN	Age/yr
Feuer, 1986[24]	New Jersey	PMR	1974–1980	263	LW/RGP/NGP	3, 8	ER	DCN	Age
Morton, 1984[25]	Portland, Vancouver	Incidence (SIR)	1963–1977	1678	RGP	4	TR	TRV	Age
Dubrow, 1983[26]	British & USA	Cohort mortality (SMR)	1950–1977	—	—	4	AR	DC	None
Musk, 1978[27]	US	Cohort mortality (SMR)	1915–1975	5655	RGP, NGP	4	ER	DC	Age
Berg 1975[28]	US, Great Britain	Cohort mortality (SMR) PMR	1949–1953 and 1959–1963	—	NGP	4	DC	DC	Age
Stang, 2003[29]	Germany	Case–control OR)	1995–1997	269 (cases) 797 (controls)	RGP	4	ER	MR	Age
Bates, 2001[30]	New Zealand	Cohort mortality (SMR) Incidence (SIR)	1977–1995	4221	NGP	3	AR	DC, TR	Age/yr
Firth, 1996[31]	New Zealand	Incidence (SIR)	1972–1984	26207	NED	4	TR	TR	Age
Deschamps 1995[32]	France	Cohort mortality (SMR)	1977–1991	830	NGP	2	ER	DCN	Age
Delahunt, 1995[33]	New Zealand	Case–control (RR)	1978–1986	710 (cases) 12,756 (controls)	NGP	4	TR	TR	Age/smoke
Aronson, 1994[34]	Canada	Cohort mortality (SMR)	1950–1989	5414	RGP	3, 6, 7	ER	DCN	Age/yr
Tornling, 1994[35]	Sweden	Cohort mortality (SMR) Incidence (SIR)	1931–1983	1153	LGP	1, 3, 7	ER	DC, TR	Age/yr
Giles, 1993[36]	Australia	Incidence (SIR)	1980–1989	2865	RGP	3, 6, 7	TRV	TR	Age
Guidotti, 1993[37]	Canada	Cohort mortality (SMR)	1927–1987	3328	RGP	2	ER	DCN	Age/yr
Hansen, 1990[38]	Denmark	Cohort mortality (SMR)	1970–1980	886	NED	4	OTH	DC	Age

(Continued)

TABLE 1
Continued

Reference	Company Location	Design/Analysis	Study Period	Number of Workers	Comparison Group	Exposure Variable	Exposure Source	Cancer Source	Cofactors
Eliopulos, 1984[39]	Australia	Cohort mortality (SMR) PMR	1939–1978	990	RGP	3	ER	DC	Age/yr
Mastromatteo, 1959[40]	Canada	Cohort mortality (SMR)	1921–1953	1039	RGP	4	DC	DC	Age

Exposure Variables
1. Number of firefighter runs
2. Duration of "active" duty
3. Duration of employment overall as a firefighter
4. Occupation (based on death certificate or tumor registry)
5. Company type engine, ladder
6. Time since first employment
7. Age-specific
8. Employment status

Exposure or Cancer Source
ER, employment records
MR, medical records
AR, association records
DC, death certificate
DCN, death certificate nosologist
TR, tumor registry with no validation
TRV, tumor registry (occupation) with validation from external sources
OTH, other

Design/Analysis
RR, rate ratio
SMR, standardized mortality/morbidity ratio
MOR, mortality odds ratio
OR, odds ratio
PMR, proportional mortality ratio
SIR, standardized incidence mortality

Comparison Group
INT = internal
LW = local workers
LGP = local general population
RGP = regional general population
NGP = national general population
NED = national employment database

engine exhausts, and organic solvents).[52–57] Benjamin et al[58] reported that blacks compared with whites have at least double the risk of being diagnosed with multiple myeloma and twice the mortality rate. Race may be ruled out as a potential factor among firefighters, because cancer risk was investigated primarily for whites.

The analyses for non-Hodgkin's lymphoma were consistent across a diversity of study designs, including SMR, PMR, SIR, and OR incident/mortality studies. All showed elevated meta-risk or point estimates. The overall summary risk estimate was significantly elevated at 1.51 (95% CI = 1.31–1.73). Hence, non-Hodgkin's lymphoma is considered a probable cancer risk for firefighters. Non-Hodgkin's lymphoma is, however, several cancer types with five International Classification of Disease (ICD) codes (200, 202.0, 202.1, 202.8, 202.9). Of importance is how the definition of non-Hodgkin's lymphoma by ICD code may contribute to the variability in study findings. For example, in a study by Demers et al[19] comparing firefighters with police, the mortality incidence density ratio for "lymphosarcoma and reticulosarcoma" (ICD 200) was not elevated (0.81)[19] but was (1.40) for "other lymphatic/hematopoietic" (ICD 202, 203). Subsequent to the time period covered in this review, Ma et al[59] examined Florida firefighters but evaluated only one of two cancers for ICD code 200, ie, lymphosarcoma but not reticular sarcoma and found nonsignificance (SMR = 0.94). Hence, these studies demonstrate the importance of being cognizant that differences in cancer risk estimates and interpretation of risk may be influenced by outcome definition.

Results showing a probable association for prostate cancer is curious. Prostate cancer is the most common malignancy affecting men and is the second leading cause of cancer.[60] Risk of developing prostate cancer is associated with advancing age, black

TABLE 2

Metarelative Risk Estimates and Test for Inconsistency for Mortality and Incidence*

Disease	Number of Studies	Reference	Observed	Expected	Metarelative Risk	95% Confidence Interval	P Value Inconsistency
Mortality studies							
Standardized mortality ratio (SMR)							
All causes (001–999)	12	13, 19, 23, 27, 30, 32, 34 35, 37–40	8384	9273.8	0.90	0.85–0.97	<0.00
All cancers (140–209)	13	13, 19, 23, 27, 30, 32, 34 35, 37–40, 51	1801	1799.9	1.00	0.93–1.08	0.02
Buccal cavity and pharynx (140–149)	5	13, 19, 32, 34, 37	34	29.8	1.14	0.79–1.60	0.84
Esophagus (150)	4	13, 19, 23, 34	17	25.1	0.68	0.39–1.08	0.62
Stomach (151)	7	13, 19, 23, 30, 34, 35, 37	75	81.3	0.92	0.73–1.16	0.72
Colon (153)	10	13, 19, 23, 26, 28, 30, 34, 35, 37, 51	252	188.3	1.34	1.01–1.79	<0.00
Rectum (154)	6	13, 19, 23, 30, 34, 35	54	40.7	1.33	1.00–1.73	0.43
Liver/gallbladder (155–156)	5	13, 19, 23, 34, 35	22	21.9	1.00	0.63–1.52	0.92
Pancreas (157)	6	13, 19, 23, 34, 35, 37	63	64.2	0.98	0.75–1.26	0.58
Larynx (161)	3	13, 19, 34	8	13.7	0.58	0.25–1.15	0.82
Lung (162)	8	13, 19, 30, 34, 35, 37, 38, 51	378	359.2	1.05	0.95–1.16	0.50
Skin (173)	3	13, 19, 37	16	15.7	1.02	0.58–1.66	0.68
Malignant melanoma (172)	2	30, 34	4	5.9	0.67	0.18–1.70	0.23
Prostate (185)	6	13, 19, 23, 34, 35, 37	104	91	1.14	0.93–1.39	0.67
Testis (186)	1	34	3	1.2	2.50	0.50–7.30	—
Bladder (188)	6	13, 19, 23, 30, 34, 37	41	33.0	1.24	0.68–2.26	0.03
Kidney (189)	6	13, 19, 23, 34, 35, 37	30	30.9	0.97	0.44–2.13	0.01
Brain and nervous system (191–192)	8	13, 19, 23, 27, 30, 34, 35, 37	64	46.1	1.39	0.94–2.06	0.07
Non-Hodgkin's lymphoma (200, 202)	3	13, 19, 34	30	20.6	1.46	0.98–2.08	0.92
Hodgkin's disease (201)	2	19, 34	4	5.1	0.78	0.21–2.01	0.59
Multiple myeloma (203)	4	13, 26, 34, 51	24	14.2	1.69	1.08–2.51	0.15
Leukemia (204–208)	2	13, 19	30	29.9	1.00	0.68–1.43	0.27
Proportional mortality ratio (PMR)							
All cancers (140–209)	6	16, 24, 39, 48, 49, 50	2443	2215.7	1.10	1.06–1.15	0.64
Buccal cavity and pharynx (140–149)	—		—	—	—	—	—
Esophagus (150)	—		—	—	—	—	—
Stomach (151)	—		—	—	—	—	—
Colon (153)	4	28, 48, 49, 50	99	79.2	1.25	0.90–1.74	0.08
Rectum (154)	1	16	37	25	1.48	1.05–2.05	—
Liver/gallbladder (155–156)	—		—	—	—	—	—
Pancreas (157)	—		—	—	—	—	—
Larynx (161)	—		—	—	—	—	—
Lung (162)	4	16, 48, 49, 50	773	742.1	1.04	0.88–1.23	0.04
Skin (172–173)	2	16, 24	42	24.8	1.69	1.22–2.29	0.41
Malignant melanoma (172)	2	48, 49	9	4	2.25	1.03–4.27	0.49
Prostate (185)	—		—	—	—	—	—

(Continued)

TABLE 2
Continued

Disease	Number of Studies	Reference	Observed	Expected	Metarelative Risk	95% Confidence Interval	*P* Value Inconsistency
Testis (186)	—		—	—	—	—	—
Bladder (188)	1	16	37	37.4	0.99	0.70–1.37	—
Kidney (189)	1	16	53	36.8	1.44	1.08–1.89	—
Brain and nervous system (191–192)	4	16, 48, 49, 50	64	54.9	1.17	0.90–1.49	0.27
Non-Hodgkin's lymphoma (200, 202)	1	16	66	50	1.32	1.02–1.67	—
Hodgkin's disease (201)	—		—	—	—	—	—
Multiple myeloma (203)	4	16, 48, 49, 50	46	32.5	1.42	1.04–1.89	0.88
Leukemia (204–208)	2	16, 24	65	53.5	1.21	0.94–1.55	0.47
Relative risk (RR)							
All causes (001–999)	—	—	—	—	—	—	—
All cancers (140–209)	2	20, 21	291	295.6	0.98	0.87–1.10	0.17
Buccal cavity and Pharynx (140–149)	1	20	11	7.7	1.43	0.71–2.57	—
Esophagus (150)	1	20	12	5.9	2.03	1.05–3.57	—
Stomach (151)	2	20, 21	25	20.6	1.21	0.80–1.81	0.55
Colon (153)	2	20, 21	25	27.5	0.91	0.60–1.36	0.92
Rectum (154)	1	20	13	9	1.44	0.77–2.49	—
Liver (155–156)	—	—	—	—	—	—	—
Pancreas (157)	1	20	17	13.6	1.25	0.73–2.00	—
Larynx (161)	1	20	3	3.8	0.79	0.17–2.35	—
Lung (162)	1	20	60	71.4	0.84	0.64–1.08	—
Skin (172–173)	1	20	7	4.1	1.71	0.68–3.49	—
Malignant melanoma (172)	—	—	—	—	—	—	—
Prostate (185)	2	20, 21	19	24.3	0.78	0.13–4.82	<0.00
Testis (186)	—	—	—	—	—	—	—
Bladder (188)	—	—	—	—	—	—	—
Kidney (189)	1	20	4	5.9	0.68	0.19–1.74	—
Brain and nervous system (191–192)	2	20, 21	9	7.1	1.26	0.55–2.34	0.14
Non-Hodgkin's lymphoma (200, 202)	—	—	—	—	—	—	—
Hodgkin's disease (201)	—	—	—	—	—	—	—
Multiple myeloma (203)	—	—	—	—	—	—	—
Leukemia (204–208)	1	20	6	9.8	0.61	0.22–1.33	—
Incidence studies (SIR)							
All cancers (140–209)	3	30, 35, 36	367	366.6	1.00	0.90–1.11	0.61
Buccal cavity and pharynx (140–149)	2	18, 36	25	19.6	1.28	0.83–1.88	0.73
Esophagus (150)	2	18, 30	10	7.6	1.32	0.63–2.42	0.51
Stomach (151)	3	18, 30, 35	38	24.1	1.58	1.12–2.16	0.33
Colon (153)	4	18, 30, 35, 36†	59	65.3	0.9	0.69–1.17	0.37
Rectum (154)	3	18, 30, 35	41	36.1	1.14	0.81–1.54	0.4
Liver (155–156)	1	35	4	4.7	0.85	0.23–2.18	—
Pancreas (157)	4	18, 30, 35, 36	22	18.2	1.21	0.76–1.83	0.83
Larynx (161)	2	18, 31	13	8.3	1.57	0.17–14.51	<0.00
Lung (162)	4	18, 30, 35, 36	111	120.0	0.93	0.76–1.11	0.83
Skin (172–173)	1	35	5	3.3	1.52	0.49–3.54	—
Malignant melanoma (172)	4	18, 30, 35, 36	60	47.9	1.25	0.96–1.61	0.87
Prostate (185)	4	18, 30, 35, 36	147	114.1	1.29	1.09–1.51	0.56

(Continued)

TABLE 2
Continued

Disease	Number of Studies	Reference	Observed	Expected	Metarelative Risk	95% Confidence Interval	*P* Value Inconsistency
Testis (186)	2	30, 36	21	11.5	1.83	1.13–2.79	0.15
Bladder (188)	2	18, 30	31	29.9	1.04	0.70–1.47	0.67
Kidney (189)	3	18, 30, 35	11	18	0.61	0.30–1.09	0.69
Brain and nervous system (191–192)	3	18, 30, 35	19	15.4	1.23	0.74–1.93	0.84
Non-Hodgkin's lymphoma (200–202)	1	36	4	2.2	1.82	0.49–4.65	—
Hodgkin's disease (201)	—		—	—	—	—	—
Multiple myeloma (203)	—		—	—	—	—	—
Leukemia (204–208)	4	18, 25, 30, 36	18	12.9	1.4	0.82–2.21	0.36

Note. Codes of the International Classification of Causes of Death (9th Revision) in parentheses; published data for references 48–50 in Howe and Birch.[4]

*Meta analysis completed only for two or more studies.

†Reference 36 is a combination of colon and rectum cancers.

TABLE 3
Mortality and Incidence Studies for Case–Control/Mortality Odds Ratio Studies

	Outcome	References	Odds Ratio	95% Confidence Interval
All cancers (140–209)	Mortality	14	1.10	1.10–1.20
Buccal cavity and pharynx (140–149)	Mortality	14	5.90	1.90–18.30
Esophagus (150)	Mortality	14	0.90	0.70–1.30
Stomach (151)	Mortality	14	1.20	0.90–1.60
Colon (153)	Mortality	14	1.00	0.90–1.20
	Incidence	22*	1.04	0.59–1.82
Rectum (154)	Mortality	14	1.10	0.80–1.60
	Incidence	22*	0.97	0.50–1.88
Liver/gallbladder (155–156)	Mortality	14	1.20	0.90–1.70
Pancrease (157)	Mortality	14	1.20	1.00–1.50
	Incidence	22*	3.19	0.72–14.15
Larynx (161)	Mortality	14	0.80	0.40–1.30
Lung (162)	Mortality	14	1.10	1.00–1.20
	Incidence	22*	1.30	0.84–2.03
Skin (172–173)	Mortality	14	1.00	0.50–1.90
Malignant melanoma (172)	Mortality	14	1.40	1.00–1.90
	Incidence	22*	1.38	0.60–3.19
Prostate (185)	Mortality	14	1.20	1.00–1.30
Testis (186)	Incidence	29	4.00	0.70–27.40
Bladder (188)	Mortality	14	1.20	0.90–1.60
	Incidence	22*	2.11	1.07–4.14
Kidney (189)	Mortality	14	1.30	1.00–1.70
	Incidence	33	4.89	2.47–8.93
Brain and nervous system (191–192)	Mortality	14	1.00	0.80–1.40
	Incidence	22*	1.52	0.39–5.92
Non-Hodgkin's lymphoma (200, 202)	Mortality	14,15†	1.41	1.10–1.70
	Incidence	22*	3.27	1.19–8.98
Hodgkin's disease (201)	Mortality	14	2.40	1.40–4.10
Multiple myeloma (203)	Mortality	14	1.10	0.80–1.60
	Incidence	17	1.90	0.50–9.40
Leukemia (204–208)	Mortality	14	1.10	0.80–1.40
	Incidence	22*	2.67	0.62–11.54

*Two control groups available; police rather than state employees selected as most comparable. Significance difference only for malignant melanoma when using state employees odds ratio and 95% confidence interval was 2.92 (1.70–5.03).

†Mortality odds ratio (mOR) calculated only for non-Hodgkin lymphoma as only case–control study with at least two studies. mOR estimated based primarily on larger sample in Ma et al.[15]

TABLE 4

Likelihood of Cancer Risk Among Firefighters After Employing Pattern of Metarelative Risk Association, Study Type, and Inconsistency Among Studies

	Criteria 1							Criteria 2		Criteria 3	
	Pattern of Metarelative Risk Association										
Cancer Site	mSMR	mPMR	mSMR and PMR	mRR	mSIR	mOR	Likelihood of Cancer Risk	Study Type	Likelihood of Cancer Risk	Inconsistency	Likelihood of Cancer Risk
Buccal	+	NA	NC	NC	+	−	Possible	No change	Possible	No change	Possible
Stomach	−	NA	NC	+	++	−	Probable	Down one	Possible	No change	Possible
Colon	++	+	++	−	−	−	Probable	No change	Probable	Down one	Possible
Rectum	+	NC	++	NC	+	−	Probable	Down one	Possible	No change	Possible
Skin	−	++	++	NC	NC	−	Probable	Down one	Possible	No change	Possible
Malignant melanoma	−	++	−	NA	+	−	Probable	Down one	Possible	No change	Possible
Prostate	+	NA	NC	−	++	−	Probable	No change	Probable	No change	Probable
Testis	NC	NA	NC	NA	++	−	Possible	No change	Possible	No change	Possible
Brain	+	+	+	+	+	−	Possible	No change	Possible	No change	Possible
Non-Hodgkin's lymphoma	+	NC	++	NA	NC	++	Probable	No change	Probable	No change	Probable
Multiple myeloma	++	++	++	NA	NA	−	Probable	No change	Probable	No change	Probable
Leukemia	−	+	+	NC	+	−	Possible	No change	Possible	No change	Possible

Pattern of meta-relative risk: "++" meta-relative risk is significant at the 5% level and >1.1; "+" meta-relative risk is not significant at the 5% level but <1.1; "−" meta-relative risk is ≤1.1 and not significant at the 5% level.

NA indicates no available studies; NC, not able to calculate because only one study of that type available.

Study type: down one level, the metarelative risk (++) is based primarily on mPMR studies and/or negative (−) mSMR studies.

Inconsistency among studies: down one level heterogeneity significant among all combined studies at the 10% level.

ethnicity, a positive family history, and may be influenced by diet. Although the positive association with prostate cancer may be due to some of these factors, it is unlikely that these entirely explain the findings; most studies analyzed white men adjusting for age. The summary risk estimate was 1.28 (95% CI = 1.15–1.43). The mSIR was significantly elevated, and all individual studies showed excess SIR values. Parent and Siemiatycki,[61] in a review article, concluded that there was suggestive epidemiologic evidence for prostate cancer associated with exposure to pesticides and herbicides, metallic dusts, metal working fluids, polycyclic aromatic hydrocarbon, and diesel engine emissions. Certainly firefighters are exposed to these latter two agents. Recently, exposure to complex mixture in the semiconductor industry also has been associated with an increase in prostate cancer.[62] Thus, it is possible that some of the mixed exposures experienced by firefighters may be prostate carcinogens. Ross and Schottenfeld[63] have cautioned, however, against associating occupational exposures with prostate cancer.

Although there were only four studies evaluating testicular cancer, we propose upgrading the likelihood of cancer risk from possible to probable. This upgrade is suggested because testicular cancer had the largest summary point estimate (2.02, 95% CI = 1.30–3.13) as well as consistency among the one SMR study, two incidence studies, and one case–control study showing elevated risk estimates between 1.15 and 4.30. Testicular cancer is the most common malignancy between the ages of 20 and 34. Except for cryptorchism, no risk factor has been clearly demonstrated.[64] Because testicular cancer occurs among younger men with high survival, mortality studies are less germane. Bates et al[30] showed an increase in the incident cases of testicular cancer with firefighter exposure duration as follows: 10 years:

TABLE 5
Summary of Likelihood of Cancer Risk and Summary Risk Estimate (95% CI) Across All Types of Studies for All Cancers

Cancer Site	Likelihood of Cancer Risk by Criteria	Summary Risk Estimate (95% CI)	Comments
Multiple myeloma	Probable	1.53 (1.21–1.94)	Consistent with mSMR and PMR (1.50, 95% CI = 1.17–1.89) Based on 10 analyses Heterogeneity—not significant at the 10% level Only two SMR and another PMR studies
Non-Hodgkin lymphoma	Probable	1.51 (1.31–1.73)	Slightly higher than mSMR and PMR (1.36, 95% CI = 1.10–1.67) Based on eight analyses Heterogeneity—not significant at the 10% level
Prostate	Probable	1.28 (1.15–1.43)	Consistent with mSIR (1.29, 95% CI = 1.09–1.51) Based on 13 analyses Heterogeneity—not significant at the 10% level
Testis	Possible	2.02 (1.30–3.13)	Slightly higher than mSIR (1.83, 95% CI = 1.13–2.79) Based on four analyses Heterogeneity—not significant at the 10% level
Skin	Possible	1.39 (1.10–1.73)	Slightly lower than mSMR and PMR (1.44, 95% CI = 1.10–1.87) – derived on basis of PMR studies Based on eight analyses Heterogeneity—not significant at the 10% level
Malignant melanoma	Possible	1.32 (1.10–1.57)	Slightly higher than mSMR and PMR (1.29, 95% CI = 0.68–2.20) Based on 10 analyses Heterogeneity—not significant at the 10% level
Brain	Possible	1.32 (1.12–1.54)	Slightly higher than mSMR and PMR (1.27, 95% CI = 0.98–1.63) Based on 19 analyses Heterogeneity—not significant at the 10% level; there was heterogeneity among SMR studies
Rectum	Possible	1.29 (1.10–1.51)	Slightly lower than mSMR and PMR (1.39, 95% CI = 1.12–1.70) Based on 13 analyses Heterogeneity—not significant at the 10% level
Buccal cavity and pharynx	Possible	1.23 (0.96–1.55)	Slightly higher than mSMR (1.18, 95% CI = 0.81–1.66) Based on nine analyses Heterogeneity—not significant at the 10% level
Stomach	Possible	1.22 (1.04–1.44)	Lower than mSIR (1.58, 95% CI = 1.12–2.16); Based on 13 analyses Heterogeneity—not significant at the 10% level
Colon	Possible	1.21 (1.03–1.41)	Slightly lower than mSMR and PMR (1.31, 95% CI = 1.08–1.59) Based on 25 analyses Heterogeneity—significant at the 10% level; there were heterogeneity among SMR and PMR studies
Leukemia	Possible	1.14 (0.98–1.31)	Similar to mSMR and PMR (1.14, 95% CI = 0.92–1.39) Based on eight analyses Heterogeneity—not significant at the 10% level
Larynx	Unlikely	1.22 (0.87–1.70)	Higher than mSMR (0.58, 95% CI = 0.25–1.15) Based on seven analyses Heterogeneity—not significant at the 10% level
Bladder	Unlikely	1.20 (0.97–1.48)	Similar to mSMR and PMR (1.24, 95% CI = 0.83,1.49) Based on 11 analyses Heterogeneity—significant at the 10% level; there was heterogeneity among SMR studies
Esophagus	Unlikely	1.16 (0.86–1.57)	Higher than mSMR (0.68, 95% CI = 0.39–1.08) Based on eight analyses Heterogeneity—not significant at the 10% level
Pancreas	Unlikely	1.10 (0.91–1.34)	Slightly higher than mSMR (0.98, 95% CI = 0.75–1.26) Based on 13 analyses Heterogeneity—not significant at the 10% level
Kidney	Unlikely	1.07 (0.78–1.46)	Similar to mSMR and PMR (1.23, 95% CI = 0.94–1.59) Based on 12 analyses Heterogeneity—significant at the 10% level; there was heterogeneity among SMR studies

(Continued)

TABLE 5
Continued

Cancer Site	Likelihood of Cancer Risk by Criteria	Summary Risk Estimate (95% CI)	Comments
Hodgkin's disease	Unlikely	1.07 (0.59–1.92)	Higher than mSMR (0.78, 95% CI = 0.21–2.01) Based on three analyses Heterogeneity—not significant at the 10% level
Liver	Unlikely	1.04 (0.72–1.49)	Similar to mSMR (1.00, 95% CI = 0.63–1.52) Based on seven analyses Heterogeneity—not significant at the 10% level
Lung	Unlikely	1.03 (0.97–1.08)	Similar to mSMR and PMR (1.05, 95% CI = 0.96–1.14) Based on 19 analyses Heterogeneity—not significant at the 10% level; there was heterogeneity among PMR studies
All cancers	Unlikely	1.05 (1.00–1.09)	Similar to mSMR and PMR (1.06, 95% CI = 1.02–1.10 Based on 25 analyses Heterogeneity—significant at the 10% level; there was heterogeneity among SMR studies

CI indicates confidence interval; SMR, standardized mortality ratio; PMR, proportional mortality ratio; SIR, standardized incidence ratio.

SIR = 1.39, 95% CI = 0.2–5.0; 11 to 20 years: SIR = 4.03, 95% CI = 1.3–9.4. In those exposed greater than 20 years, the risk estimate remained elevated but declined (SIR = 2.65, 95% CI = 0.3–9.6), possibly because testicular cancer generally occurs at a younger age. Bates et al[30] argued that, although the reason for the excess risk of testicular cancer remained obscure, the possibility that this is a chance finding was low because incident studies are likely the most appropriate methodology for a cancer that can be successfully treated.

The 1990 findings of Howe and Burch[4] showing a positive association with brain cancer and malignant melanoma are compatible with our results because both had significant summary risk estimates. Brain cancers were initially scored as probable but then downgraded to possible (Table 5). There was inconsistency among the SMR studies, which resulted in the use of the random-effects model, yielding confidence limits that were not significant (SMR = 1.39, 95% CI = 0.94–2.06) (Table 2). This inconsistency primarily resulted from the Baris et al study,[13] a 61-year follow up of 7789 firefighters demonstrating a marked reduction in brain cancer (SMR = 0.61, 95% CI = 0.31–1.22). As noted in Table 4, however, there were elevated, but not significant, risk estimates across all studies, ie, mSMR, mPMR, mRR, and mSIR. This consistency is all the more remarkable given the diversity of rare cancers included in the category "brain and nervous system." Furthermore, there was a 2003 study by Krishnan et al[65] published after our search that examined adult gliomas in the San Francisco Bay area of men in 35 occupational groups. This study showed that male firefighters (six cases and one control) had the highest risk with an odds ratio of 5.93, although the confidence intervals were wide and not significant. In addition, malignant melanoma was also initially scored as probable but was downgraded to "possible" due to study type. This study downgrade was related to the negative SMR (−) and reliance primarily on a PMR study. Thus, in conclusion, our study supports a probable risk for multiple myeloma, similar to Howe and Burch's[4] findings, and a possible association with malignant melanoma and brain cancer.

Summary

We implemented a qualitative three-criteria assessment in addition to the quantitative meta-analyses. Based on the more traditional quantitative summary risk estimates shown in Table 5, 10 cancers, or half, were significantly associated with firefighting after the three cancers were designated as a probable risk based on the quantitative meta-risk estimates and our three criteria assessment. These cancers included multiple myeloma, non-Hodgkin's lymphoma, and prostate. A recommendation is also made, however, for upgrading testicular cancer to "probable" based on the twofold excess summary risk estimate and the consistency among the studies. Thus, firefighter risk for these four cancers may be related to the direct effect associated with exposures to complex mixtures, the routes of delivery to target organs, and the indirect effects associated with modulation of biochemical or physiologic pathways. In anecdotal conversations with firefighters, they report that their skin, including the groin area, is frequently covered with "black soot." It is noteworthy that testicular cancer had the highest summary risk estimate (2.02) and skin cancer had a summary risk estimate (1.39) higher than prostate (1.28). Certainly, Edelman et al[3] at the World Trade Center, although under extreme conditions, revealed the hazards that firefighters may encounter only because air monitoring was performed.

As noted in Table 1, approximately half of the studies used local, regional, or national general population rates as the comparison group. These general population comparison groups raise concern that the actual risk of cancer may be underestimated due to the healthy worker effect related to the strict physical entry requirements, maintenance of better physical fitness, and good health benefits. The healthy worker bias may be less pronounced, however, for cancer than for conditions such as coronary heart disease. Furthermore, tobacco is unlikely a contributing factor because cancers known to be associated with smoking such as lung, bladder, and larynx were designated as unlikely and corresponding summary risk estimates were not statistically significant.

These findings of an association of firefighting with significant increased risk for specific types of cancer raise red flags and should encourage further development of innovative comfortable protective equipment allowing firefighters to do their jobs without compromising their health. Studies are especially needed that better characterize the type and extent of exposures to firefighters.

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